PRELIMINARY SURVEY REPORT:

PRE-INTERVENTION QUANTITATIVE RISK FACTOR ANALYSIS

FOR SHIP CONSTRUCTION PROCESSES

at

JEFFBOAT LLC
Jeffersonville, Indiana

REPORT WRITTEN BY:
Stephen D. Hudock, Ph.D., CSP, NIOSH
Steven J. Wurzelbacher, M.S., NIOSH
Ova E. Johnston, NIOSH

REPORT DATE:
August 2001

REPORT NO.:
EPHB 229-11a

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Applied Research and Technology (DART)
Engineering and Physical Hazards Branch (EPHB)
4676 Columbia Parkway, Mailstop R-5
Cincinnati, Ohio 45226

PLANT SURVEYED:	Jeffboat LLC, A unit of American Commercial Lines Holdings LLC, 1030 East Market Street Jeffersonville, Indiana 47130-4330
SIC CODE:	3731
SURVEY DATE:	November 9-10, 1999
SURVEY CONDUCTED BY:	Stephen D. Hudock, Ph.D., CSP Steven J. Wurzelbacher, Industrial Hygienist Ova E. Johnston, Engineering Technician Karl V. Siegfried, MEMIC Safety Services, Portland, Maine
EMPLOYER REPRESENTATIVES CONTACTED:	Stephen R. Morris, CSE, CSM, ASP, Director of Safety - Shore Facilities David Temple, NREMTB, Safety Assistant Gary Neese, Structural Shop Supervisor
EMPLOYEE REPRESENTATIVES CONTACTED:	Michael Everhart, Chief Union Steward Teamsters Local Union 89
MANUSCRIPT EDITED BY:	Anne Votaw

DISCLAIMER

Mention of company names and/or products does not constitute endorsement by the Centers for Disease Control and Prevention (CDC) or NIOSH.

ABSTRACT

A pre-intervention quantitative risk factor analysis was performed at various shops and locations within Jeffboat LLC, a builder of river barges in Indiana, as a method to identify and quantify risk factors that workers may be exposed to in the course of their normal work duties. This survey was conducted as part of a larger project, funded through Maritech Advanced Shipbuilding Enterprise and the U.S. Navy, to develop projects to enhance the commercial viability of domestic shipyards. Four locations were identified: the rake frame subassembly process, the unloading of angle irons in the steelyard, the honeycomb confined space welding process for double hull barges, and the shear press operation in the plate shop. The application of exposure assessment techniques provided a quantitative analysis of the risk factors associated with the individual tasks. Possible engineering interventions to address these risk factors for each task are briefly discussed.

I. INTRODUCTION

IA. BACKGROUND FOR CONTROL TECHNOLOGY STUDIES

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency in occupational safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposures to potential chemical and physical hazards. The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, EPHB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial processes, or specific control techniques. Examples of the completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a greater general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

IB. BACKGROUND FOR THIS STUDY

The domestic ship building, ship repair, and ship recycling industries have historically had much higher injury/illness incidence rates than those of general industry, manufacturing, or construction. For 1998, the latest year available, the Bureau of Labor Statistics reported that shipbuilding and repair (SIC 3731) had a recordable injury/illness incidence rate of 22.4 per 100 full-time employees (FTE), up from 21.4 in 1997. By contrast, in 1998, the manufacturing sector reported a rate of 9.7 per 100 FTE, construction reported a rate of 8.8 per 100 FTE, and all industries reported a rate of 6.7 injuries/illnesses per 100 FTE. When only lost workday cases for 1998 are considered, shipbuilding and repair had an incidence rate of 11.5 per 100 FTE, compared to manufacturing at 4.7, construction at 4.0, and all industries at 3.1 lost workday

injuries/illnesses per 100 FTE. Historical trends for total recordable cases and lost workday cases have shown downward trends for each of these sectors and industries, as shown in Figures 1 and 2.

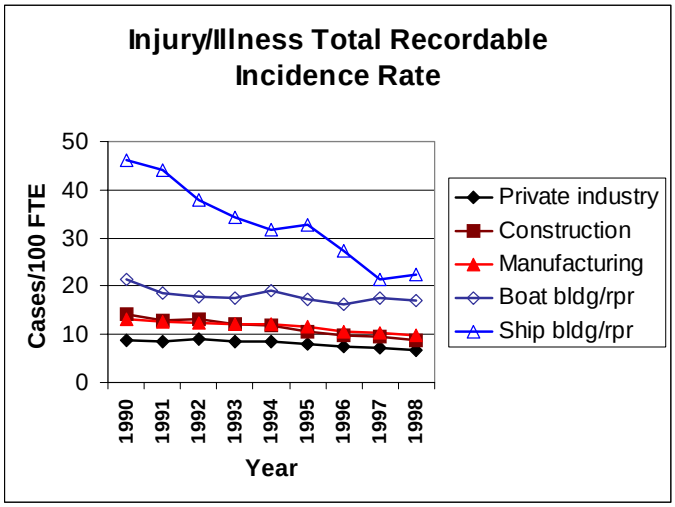

Figure 1. Injury/Illness Total Recordable Incidence Rate

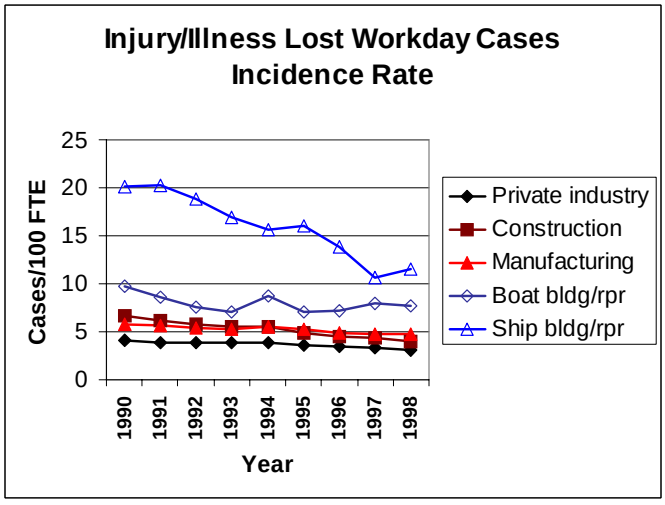

Figure 2. Injury/Illness Lost Workday Cases Incidence Rate

When shipbuilding and repairing are compared to the manufacturing sector for injuries and illnesses to specific parts of the body that result in days away from work for the year 1997, shipbuilding is significantly higher in a number of instances. For injuries and illnesses to the trunk, including the back and shoulder, shipbuilding reported an incidence rate of 207.7 cases per 10,000 FTE, compared to manufacturing at 82.1 cases. For injuries and illnesses solely to the back, shipbuilding reported 111.1 cases per 10,000 FTE, compared to manufacturing's incidence rate of 52.2 cases. For the lower extremity, shipbuilding reported 145.0 cases per 10,000 FTE compared to manufacturing at 40.8 cases. For upper extremity injuries and illnesses, shipbuilding reported an incidence rate of 92.2 cases per 10,000 FTE while manufacturing reported 73.4 cases.

When shipbuilding and repairing are compared to the manufacturing sector, by nature of injury, for injuries and illnesses resulting in days away from work for the year 1997, shipbuilding is significantly higher in a number of categories. For sprains and strains, shipbuilding reported an incidence rate of 237.9 cases per 10,000 FTE, compared to manufacturing's incidence rate of 91.0 cases. For fractures, shipbuilding reported 41.7 cases per 10,000 FTE, compared to manufacturing at 15.8 cases. For bruises, shipbuilding reported 61.3 cases per 10,000 FTE, compared to manufacturing at 21.5 cases. The median number of days away from work for shipbuilding and repairing is 12 days, compared to manufacturing and private industry's median of 5 days.

Beginning in 1995 the National Shipbuilding Research Program began funding a project looking at the implementation of ergonomic interventions at a domestic shipyard as a way to reduce workers' compensation costs and to improve productivity for targeted processes. That project came to the attention of the Maritime Advisory Committee for Occupational Safety and Health (MACOSH), a standing advisory committee to OSHA. NIOSH began an internally funded project in 1997 looking at ergonomic interventions in new ship construction facilities. In 1998, the U.S. Navy decided to fund a number of research projects looking to improve the commercial viability of domestic shipyards, including projects developing ergonomic interventions for various shipyard tasks or processes. Project personnel within NIOSH successfully competed in the project selection process. The Institute currently receives external project funding from the U.S. Navy through an organization called Maritech Advanced Shipbuilding Enterprise, a consortium of major domestic shipyards.

Shipyards that participated in the NIOSH project receive an analysis of their injury/illness data, have at least one ergonomic intervention implemented at their facility, and have access to a web site documenting ergonomic solutions found throughout the domestic maritime industries. The implementation of ergonomic interventions in other industries has resulted in decreases in workers' compensation costs and increases in productivity.

Researchers identified seven participating shipyards and analyzed individual shipyard recordable injury/illness databases by the end of November 1999. Ergonomic interventions will be implemented in each of the shipyards by the end of December 2000. Intervention follow-up

analysis will be completed by the end of March 2001. A series of meetings and a workshop to document the ergonomic intervention program will be held by the end of March 2001.

IC. BACKGROUND FOR THIS SURVEY

Jeffboat LLC was selected for a number of reasons. It was decided that the project should look at a variety of yards based on product, processes, and location. A private shipyard across the Ohio River from Louisville, Kentucky, Jeffboat LLC performs primarily new vessel construction. This yard is considered to be a medium- to small-size yard. The primary product of the yard is river barges of various configurations. Approximately 350 barges are completed each year. Due to the speed with which vessels are produced (approximately 19 days total), this facility comes closest to being an assembly line manufacturing facility, somewhat dissimilar to the other shipyards visited. In addition to the river barges, Jeffboat also produces the occasional towboat or vessel for the gaming and excursion industries. Jeffboat is a member of the Shipbuilders Council of America.

Looking at Jeffboat production employees for the period 1995 to 1998, NIOSH researchers found a decline in both the total incidence rate (33% reduction) and the days away from work incident rate (24% reduction). Among production workers, musculoskeletal disorders represented 27% of the total cases and 35% of the days away from work cases. Departments within Jeffboat having the highest rates and numbers of musculoskeletal disorders include the Structural Shop, Towboats, Hatch Covers, Line 4 Subassembly, Line 1 Hull, Line 1 Sides, Line 4 Hull, and the Plate Shop. These same departments had the highest rates and number of musculoskeletal disorders that resulted in days away from work. Occupations having the highest number of musculoskeletal disorders included welders and shipfitters. Musculoskeletal disorders, including those resulting in days away from work, most commonly involved the lower back.

There are several caveats that must be considered when analyzing Jeffboat injury data. For example, light duty or restricted duty work is not offered to employees who have worked for fewer than sixty days. Restricted or light duty work is allowed for workers with more than sixty days, once they have joined the local union (Teamsters). Since there is this disparity between new hires and full union members, the distribution of Days Away From Work cases may be inflated by those injuries suffered by the new hires. Also, there may be difficulty in tracking injury rates for specific workers or crews due to the high turnover rate (approximately 40%). This may make it difficult to assess intervention effectiveness, especially if crew members change.

II. PLANT AND PROCESS DESCRIPTION

IIA. INTRODUCTION

Plant Description: Jeffboat LLC calls itself "America's Largest Inland Shipbuilder." Jeffboat is located in Jeffersonville, Indiana, across the Ohio river from Louisville, Kentucky. The shipyard has been in business at its present location since 1939, initially known as the Howard Ship Yards, then as the Jeffersonville Boat & Machine Company, or Jeffboat, making 123 landing craft, 26 submarine chasers, and hundreds of other vessels for the U.S. Navy during World War II. Jeffboat's primary products now are barges, towboats, and an occasional paddlewheeler. The shipyard facilities include over a mile of waterfront property, 4 drydocks and approximately 50 acres of property.

Corporate Ties: A unit of American Commercial Lines Holdings LLC

Products: Jeffboat produces approximately 350 barges per year in a variety of configurations based on client needs, including open hopper barges, double-hull liquid and chemical tankers, covered rake barges, and self-unloading cement barges. Occasionally, towboats and paddlewheelers for the gaming and excursion industries have been built.

Age of Plant: The site of Jeffboat has been functioning as a shipyard since 1939. Most of the facility has been updated or rebuilt since that time.

Number of Employees, etc.: At the time of the survey, Jeffboat employed approximately 975 production employees, of which 169 were new hires having less than 90 days experience with the company. Approximately 45% of the production workers are classified as welders. Annual turnover has historically been near 40%.

IIB. PROCESS DESCRIPTION

Steelyard – Steel plate, beams, and angle iron are delivered to the facility by barge, truck, or train and is stored at an outside storage yard at the far west end of the property. The steelyard is serviced by an A-frame crane that retrieves raw material from the yard and positions it for transfer to the surface preparation area..

Surface Preparation – Steel plate and shaped steel are moved from the supply yard by crane into an automatic surface preparation process. Steel is moved by conveyors through a heating process to remove any surface moisture, a steel-shot abrasive blasting area to remove any rust or mill residue, and through a paint priming system that coats the steel with an inorganic zinc coating to inhibit rusting.

Plate Shop – Steel plate is cut to size using numerical control plasma cutting tables. Sections of plate that need to be shaped are sent through massive rollers to force the steel into the proper

shape. Smaller shapes are cut with gas burners, cut to size at the shears, or punched at the punch presses. Sections of steel plate for hull bottoms and sides are welded together at this time.

Subassembly – Steel shapes are pieced together and welded to form a variety of subassemblies for the sides and hulls.

Subassembly – Rakes and Sterns – Rakes (or the curved bows of the vessels) and sterns are subassembled nearly to entirety in their own subassembly area

Final Assembly – The sides, hulls, rakes, and sterns are pieced together as part of final assembly.

Painting – Vessels are painted to customer specifications prior to launch.

IIC. POTENTIAL HAZARDS

Major Hazards: Awkward postures, manual material handling, confined space entry, welding fumes, ultraviolet radiation from welding, and paint fumes are the major hazards at Jeffboat.

III. METHODOLOGY

A variety of exposure assessment techniques were implemented where deemed appropriate to the job task being analyzed. The techniques used for analysis include 1) the Rapid Upper Limb Assessment (RULA); 2) the Strain Index; 3) a University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders; 4) the OVAKO Work Analysis System (OWAS); 5) a Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling; 6) the NIOSH Lifting Equation; 7) the University of Michigan 3D Static Strength Prediction Model; and 8) the PLIBEL method.

The RULA (McAtamney and Corlett, 1993) is a survey method developed to assess the exposure of workers to risk factors associated with work-related upper limb disorders. On using RULA, the investigator identifies the posture of the upper and lower arm, neck, trunk, and legs. Considering muscle use and the force or load involved, the investigator identifies intermediate scores, which are cross-tabulated to determine the final RULA score. This final score identifies the level of action recommended to address the job task under consideration.

The Strain Index (Moore and Garg, 1995) provides a semiquantitative job analysis methodology, that appears to accurately identify jobs associated with distal upper extremity disorders versus other jobs. The Strain Index is based on ratings of intensity of exertion, duration of exertion, efforts per minute, hand and wrist posture, speed of work, and duration per day. Each of these ratings is translated into a multiplier. These multipliers are combined to create a single Strain Index score.

The University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders (Lifshitz and Armstrong, 1986) allows the investigator to survey a job task with regard to the physical stress and the forces involved, the upper limb posture, the suitability of the workstation and tools used, and the repetitiveness of a job task. Negative answers are indicative of conditions that are associated with the development of cumulative trauma disorders.

The OWAS (Louhevaara and Suurnäkki, 1992) was developed to assess the quality of postures taken in relation to manual materials handling tasks. Workers are observed repeatedly over the course of the day and postures and forces involved are documented. Work postures and forces involved are cross-tabulated to determine an action category that recommends if, or when, corrective measures should be taken.

The NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling (Waters and Putz-Anderson, 1996) is an example of a simple checklist that can be used as a screening tool to provide a quick determination as to whether or not a particular job task is comprised of conditions that place the worker at risk of developing low back pain.

The NIOSH Lifting Equation (Waters et al., 1993) provides an empirical method to compute the recommended weight limit for manual lifting tasks. The revised equation provides methods for evaluating asymmetrical lifting tasks and less than optimal hand to object coupling. The equation allows the evaluation of a greater range of work durations and lifting frequencies. The equation also accommodates the analysis of multiple lifting tasks. The Lifting Index, the ratio of load lifted to the recommended weight limit, provides a simple means to compare different lifting tasks.

The University of Michigan 3D Static Strength Prediction Program is a useful job design and evaluation tool for the analysis of slow movements used in heavy materials handling tasks. Such tasks can best be analyzed by describing the activity as a sequence of static postures. The program provides graphical representation of the worker postures and the materials handling task. Program output includes the estimated compression on the L5/S1 vertebral disc and the percentage of population capable of the task with respect to limits at the elbow, shoulder, torso, hip, knee, and ankle.

The PLIBEL method (Kemmlert, 1995) is a checklist method that links questions concerning awkward work postures, work movements, and design of tools and the workplace to specific body regions. In addition, any stressful environmental or organizational conditions should be noted. In general, the PLIBEL method was designed as a standardized and practical assessment tool for the evaluation of ergonomic conditions in the workplace.

Four specific processes were identified for further analysis. These processes were rake frame subassemblies within the Structural Shop, angle iron unload within the Steelyard, honeycomb welding within the Line 4 Hull area, and shear operation within the Plate Shop. Each of these processes are examined in greater detail below.

IIIA. RAKE FRAME SUBASSEMBLIES WITHIN STRUCTURAL SHOP

Figure 3. Rake Frame Subassembly Area

IIIA1. Injury Data

The rake frame subassembly area has the highest overall musculoskeletal disorder (MSD) incidence rate within the shipyard, is second within the shipyard in MSD Days Away From Work incidence rate at 3.5 cases per 100 FTE, and third within the shipyard in MSD back incidence rate. Examples of recent injuries include lower back strain when angle iron being lifted slipped, bursitis in knee aggravated by crawling on stern units, and bilateral wrist tendonitis from repetitive use of handtools and holding steel in place.

IIIA2. Process

Subassemblies, such as rake frames, or the skeletal framework for the curved bows of tankers, and chemical and cargo barges, are created in this area. Three stations exist for each type of rake frame, at approximately 21.5 feet x 36 feet each. Jigs are set-up at ground level and are welded in place on the steel deck floor. The overall rake frame process is as follows:

1) Delivery of angle irons by overhead crane (ranging in size and shape) to stacks parallel to the jig set-up.

2) Placement of angle irons manually into the jig, usually done by one worker, sometimes in tandem lifts. This placement requires workers to bend extremely at the waist and to lift loads of up to about 125 pounds. Workers who do this job are very skilled and tend to slide and pivot the larger angle irons into place rather than

lift the entire load. Smaller irons (ranging in size from 45 to 90 pounds) are still often lifted entirely by hand.

Figure 4. Worker moving angle iron from stockpile to jig

Figure 5. Worker placing smaller angle iron into jig

3) Angle irons are adjusted into place by the workers using their hands and gator pry bar to grip the angle irons. Wedges are then hammered into place to hold the irons steady in the jig.

4) Horizontal plates at the corners of the rake frame are manually lifted, positioned on the frame, and held in place by C-clamps, as are the smaller angle irons.

Figure 6. Shipfitter holding angle irons together with C-clamps

5) A team of two welders stick weld the joints of the rake frame that face up. Postures assumed during welding are typically bent at the waist, kneeling, or sitting on the rake frame.

Figure 7. Welding rake frame angle irons while standing

Figure 8. Welding rake frame angle irons while squatting

6) The rake frame subassembly is released by the worker knocking out the wedges with a hammer. The rake frame subassembly is then picked up, flipped over, and moved to an area adjacent to the jig by the overhead crane. Frames are stacked in piles of 6-7 frames.

7) The welders move to the stack of frames and weld the joints that are now facing up. During this process, the shipfitter and the welders are working at the same

time so that one frame is being set up as the other is finished welding together. Approximately 18-21 of these frames are done a day.

The most common trades employed within the Structural Shop are welders and shipfitters.

IIIA3. Ergonomic Risk Factors

During rake frame subassembly, shipfitters undergo awkward postures, including extreme lumbar flexion and excessive loads to low back. Welders undertake awkward postures, such as extreme lumbar flexion, shoulder abduction, wrist flexion, both ulnar and radial deviation, and kneeling on hard surfaces.

IIIA4. Ergonomic Analysis of Shipfitters in Rake Frame Subassembly

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the shipfitter in the rake frame subassembly task. A RULA analysis was not deemed appropriate because the primary concern with the shipfitter at this task appeared to be manual materials handling and poor back posture, and the RULA primarily addresses the upper limb. An Strain Index analysis was performed (Table 1) and found the following results:

1) The *Intensity of Exertion* was rated as "Hard" and given a multiplier score of 6, on a scale of 1 to 13.

2) The *Duration of Exertion* of the task was rated as 50% - 79% of the task cycle, resulting in a multiplier of 2.0, on a scale of 0.5 to 3.0.

3) The *Efforts per Minute* were noted to be between 4 and 8, resulting in a multiplier of 1.0, on a scale of 0.5 to 3.0.

4) The *Hand/Wrist Posture* was rated as "Good," resulting in a multiplier of 1.0, on a scale of 1.0 to 3.0.

5) The *Speed of Work* was rated as "Normal," resulting in a multiplier of 1.0, on a scale of 1.0 to 2.0.

6) The *Duration of Task per Day* was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75, on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 9. An SI score of between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the SI indicated that this task puts the worker at increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the rake frame shipfitter task (Table 2), of the 21 possible responses, 8 were negative, 6 were positive, and 7 were not applicable. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the rake frame shipfitter task (Table 3), corrective measures were suggested for a number of specific subtasks. These subtasks included placing the angle iron, clamping and unclamping the angle iron, hammering wedges to tighten angle irons in the jig, de-slagging the welds, and staging the angle irons prior to use.

The NIOSH checklist for manual materials handling consists of 14 items. When applied to the rake frame shipfitter task (Table 4), 6 responses were positive and 8 negative. In this checklist, positive responses are indicative of conditions that pose a risk to the worker for developing low back pain. The higher the percentage of positive responses, the greater the risk of low back pain. For the rake frame shipfitter task, this percentage was 43%.

The University of Michigan 3D Static Strength Prediction Program was used to analyze eight rake frame shipfitter subtasks (Table 5). Analysis of these subtasks resulted in estimated disc compression loads, at the L5/S1 disc, to be in excess of the NIOSH Recommended Compression Limit of 770 pounds for seven of the eight subtasks. The average estimated disc compression load was 923 pounds. The maximum estimated disc compression load was 1,531 pounds, nearly twice the recommended limit.

The PLIBEL checklist for the rake frame shipfitter task (Table 6) reported a high percentage (> 70%) of risk factors present for the neck, shoulder, upper back, elbows, forearms, hands, and lower back. Several environmental and organizational modifying factors were present as well.

IIIA5. Ergonomic Analysis of Welders in Rake Frame Subassembly

A Rapid Upper Limb Assessment was conducted for the rake frame welder tasks (Table 7). Analyses of four tasks with unique postures and a composite task each resulted in a response to "investigate and change immediately."

An SI analysis was performed for the rake frame welders (Table 8) and resulted in the following:

1) The *Intensity of Exertion* was rated as "Somewhat Hard" and given a multiplier score of 3, on a scale of 1 to 13.

2) The *Duration of Exertion* of the task was rated as 50% - 79% of the task cycle, resulting in a multiplier of 2.0, on a scale of 0.5 to 3.0.

3) The *Efforts per Minute* were noted to be nearly continuous at greater than or equal to 20 per minute, resulting in a multiplier of 3.0, on a scale of 0.5 to 3.0.

4) The *Hand/Wrist Posture* was rated as "Fair," resulting in a multiplier of 1.0, on a scale of 1.0 to 3.0.

5) The *Speed of Work* was rated as "Normal," resulting in a multiplier of 1.0, on a scale of 1.0 to 2.0.

6) The *Duration of Task per Day* was rated to be between 4 and 8 hours, resulting in a multiplier of 1.0, on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together, resulting in a final SI score. For the rake frame welder tasks the final SI score was 27. An SI score of between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the SI indicated that this task puts the worker at increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the rake frame welder task (Table 9), of the 21 items, 10 were negative and 12 were positive (1 item answered both positively and negatively). Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the rake frame welder task (Table 10), corrective measures were suggested for a number of specific subtasks. These subtasks included welding from inside the rake frame, welding while straddling the rake frame, welding from outside the rake frame, and de-slagging the welds.

The PLIBEL checklist for the rake frame welder task (Table 11) reported a moderate percentage (approximately 50%) of risk factors present for the neck, shoulder, upper back, elbows, forearms, and hands. Several environmental and organizational modifying factors were present as well.

IIIB. ANGLE IRON UNLOAD IN STEELYARD

Figure 9. Steelyard conveyor system

IIIB1. Injury Data

Injury data specific to workers in the steelyard could not be determined from available information.

IIIB2. Process

Raw material, primarily steel plate and angle irons, is brought to the shipyard by truck, train, or barge. Material is placed within the steelyard by the use of an A-frame crane and stored outside until needed by the various production departments. The task under consideration is the separation of angle irons from batch loads. The type of angle iron used within the shipyard varies greatly in size, length, and weight. Common angle irons are 5 inches by 3 inches by 40 feet in length and 5/16 inch thick. A general description of angle iron separation process follows:

1) A large A-frame crane picks up batch load of angle irons from steelyard and transports it to an unloading station.

2) After the crane releases the load on a large stand, the steel bands holding the batch together are cut using a set of shears, and one worker begins separating the load with a gator bar, which is about 3 feet long, and weighs 12.2 pounds.

Figure 10. Separating angle irons with gator bar

3) The worker grabs hold of each individual iron with the gator bar and lets it fall onto a sorting table below.

Figure 11. Flipping angle irons onto conveyor with gator bar

4) Two workers, then, pull the angle across the table either by hand or by using large, long hooks and spread the angle irons across the roller conveyor.

Figure 12. Workers positioning angle iron on roller conveyor

5) Once the angle irons are placed on the roller conveyor, the angle irons are transferred to a mobile conveyor section that places the angle irons into the surface preparation process.

IIIB3. Ergonomic Risk Factors

The gator bar worker experiences awkward postures including extreme lumbar flexion and excessive shoulder loads in separating the angle irons. The unload helpers also experience awkward postures, including moderate lumbar flexion and moderate shoulder loads in pulling the angle irons across the roller conveyor.

IIIB4. Ergonomic Analysis of Gator Bar Worker

A Rapid Upper Limb Assessment was conducted for the gator bar worker and the angle iron separation tasks (Table 12). Analyses of four tasks having unique postures and a composite task each resulted in a response of 7 on a scale of 1 to 7.

The SI analysis, performed for the gator bar worker separating angle irons (Table 13), obtained the following results:

1) The *Intensity of Exertion* was rated as “Very Hard” and given a multiplier score of 9, on a scale of 1 to 13.

2) The *Duration of Exertion* of the task was rated as 10% - 29% of the task cycle, resulting in a multiplier of 1.0, on a scale of 0.5 to 3.0.

3) The *Efforts per Minute* were recorded to be between 9 and 14 resulting in a multiplier of 1.5, on a scale of 0.5 to 3.0.

4) The *Hand/Wrist Posture* was rated as "Bad," resulting in a multiplier of 2.0, on a scale of 1.0 to 3.0.

5) The *Speed of Work* was rated as "Normal," resulting in a multiplier of 1.0, on a scale of 1.0 to 2.0.

6) The *Duration of Task per Day* was rated to be between 1 and 2 hours, resulting in a multiplier of 0.50, on a scale of 0.25 to 1.50.

The multiplier values for each segment were multiplied together resulting in a final SI score. For the gator bar worker separating angle iron, the final SI score was 13.5. An SI score of between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the SI indicated that this task put the worker at increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the gator bar worker separating angle irons (Table 14), of the 21 items, 15 were negative and 6 were positive (1 item answered both positively and negatively, 1 item not answered). Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the gator bar worker separating angle irons (Table 15), a score of 2 on a 4-point scale was obtained for the subtask of using the jaw end of the gator bar to flip the angle irons. Analyses of three other subtasks resulted in a score 4 on a 4-point scale. These subtasks included using the jaw end of the gator bar to separate angle irons, and using the pry end of the gator bar either to separate the angle irons or to lever the angle irons over.

The PLIBEL checklist for the gator bar worker separating angle irons (Table 16) reported a high percentage (approximately 80%) of risk factors present for the elbows, forearms, and hands. Moderate percentages (approximately 50%) of risk factors were present for the neck, shoulder, upper back and low back. A high percentage (approximately 80%) of environmental and organizational modifying factors are present as well.

IIIB5. Ergonomic Analysis of Steelyard Helper

A Rapid Upper Limb Assessment was conducted for the steelyard helper in the angle iron flip and layout tasks (Table 17). Analysis of one task resulted in a response of 6 on a 7-point scale. Analyses of three other tasks with unique postures and a composite task each resulted in a score of 7, on a scale from 1 to 7.

The SI analysis, performed for the steelyard helper in the angle iron flip and layout tasks (Table 18), provided the following results:

1) The *Intensity of Exertion* was rated as "Somewhat Hard" and given a multiplier score of 3, on a scale of 1 to 13.

2) The *Duration of Exertion* of the task was rated as 30% - 49% of the task cycle, resulting in a multiplier of 1.5, on a scale of 0.5 to 3.0.

3) The *Efforts per Minute* were recorded to be between 9 and 14 resulting in a multiplier of 1.5, on a scale of 0.5 to 3.0.

4) The *Hand/Wrist Posture* was rated a "Bad," resulting in a multiplier of 2.0, on a scale of 1.0 to 3.0.

5) The *Speed of Work* was rated as "Normal," resulting in a multiplier of 1.0, on a scale of 1.0 to 2.0.

6) The *Duration of Task per Day* was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75, on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final SI score. For the steelyard helper at the angle iron task, the final SI score was 10.1. An SI score of between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the SI indicated that this task put the worker at increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the steelyard helper at the angle iron task (Table 19), of the 21 items, 14 were negative and 7 were positive (1 item answered both positively and negatively, 1 item not answered). Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the steelyard helper at the angle iron task (Table 20), the subtask of dragging the angle iron along the roller conveyor resulted in a rating of 3, on a

scale of 1 to 4. Analysis of another subtask, using the jaw end of a gator bar to flip the angle iron, also resulted in a rating of 3 on a 4-point scale.

The PLIBEL checklist for the steelyard helper at the angle iron task (Table 21) reported a high percentage (approximately 73%) of risk factors present for the elbows, forearms, and hands. A moderate percentage (approximately 42%) of risk factors were present for the neck, shoulder, and upper back. A moderate percentage (approximately 60%) of environmental and organizational modifying factors were present as well.

IIIC. HONEYCOMB WELDING IN LINE 4 HULL AREA

Figure 13. Honeycomb confined space welding at Line 4 Hull area

IIIC1. Injury Data

The honeycomb welding task within the Line 4 Hull area is often the initial job of new hires once they meet the welding school qualifications. This task also tends to be somewhat difficult. The worker must enter a 2 foot by 2 foot by 16 foot long section of hull and stitch weld the bottom steel plate to the vertical supports on both sides for the entire length, using a stick welding process. The confined space can lead to awkward postures, particularly for larger individuals. This area of the shipyard is fourth in the overall number of musculoskeletal disorders, fourth in the number of musculoskeletal disorder Days Away from Work cases, and second in musculoskeletal disorder actual number of days away from work. All workers in this area are welders. Recent injuries included four ankle injuries due to slips and trips while moving between honeycombs; four low back injuries from slips, manual materials lifting, or pulling welding

leads; three knee injuries from slips and contact stresses; and three arm, wrist, or elbow injuries from pulling welding leads.

IIIC2. Process

The Line 4 Hull area is responsible for welding the double hulls for chemical and liquid tankers. This involves welding in spaces known as honeycombs, which are 2 feet by 2 feet by 16 feet long. The bottom plate is welded to the vertical supports on both sides of the honeycomb. Currently, a stick welding process is used. Typically eight to ten honeycombs can be completed in a shift by each welder. Ventilation is primarily by blower fan, forcing outside air into the honeycomb. A detailed report on ventilation interventions for this process can be found elsewhere.

Figure 14. Constrained posture of confined space honeycomb welder

IIIC3. Ergonomic Risk Factors

The welders must assume constrained postures while crawling to the far end of the honeycomb to begin welding. This task also includes extreme lumbar flexion in confined spaces, contact stress on the knees and elbows, pulling and lifting weld leads into and out of the honeycomb, positioning the blower fan and moving it from one honeycomb to the next, and extreme environmental temperatures in summer and winter.

IIIC4. Ergonomic Analysis of Honeycomb Welder in Line 4 Hull Area

A Rapid Upper Limb Assessment was conducted for the honeycomb welder task (Table 22). Analyses of four tasks with unique postures and a composite task each resulted in a score of 7, on a scale from 1 to 7.

An SI analysis, performed for the honeycomb welder task (Table 23) obtained the following results:

1) The *Intensity of Exertion* was rated as "Somewhat Hard" and given a multiplier score of 3, on a scale of 1 to 13.

2) The *Duration of Exertion* of the task was rated as 50% - 79% of the task cycle, resulting in a multiplier of 2.0, on a scale of 0.5 to 3.0.

3) The *Efforts per Minute* were recorded to be extremely static due to the nature of the process resulting in a multiplier of 3.0, on a scale of 0.5 to 3.0.

4) The *Hand/Wrist Posture* was rated as "Fair," resulting in a multiplier of 1.5, on a scale of 1.0 to 3.0.

5) The *Speed of Work* was rated as "Normal," resulting in a multiplier of 1.0, on a scale of 1.0 to 2.0.

6) The *Duration of Task per Day* was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00, on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final SI score. For the honeycomb welder task, the final SI score was 27. An SI score of between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Regardless of actual incidence rate, the SI indicated that this task put the worker at increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the honeycomb welder task (Table 24), of the 21 items, 10 were negative and 11 were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the honeycomb welder task (Table 25), a score of 2 on a scale from 1 to 4 was obtained, for the subtasks of striking the welding arc and running the bead, deslagging the weld, and changing out the welding sticks, if the back was not twisted. Otherwise, if the back was twisted, each of the subtasks resulted in a score of 4 on a scale of 1 to 4.

The PLIBEL checklist for the honeycomb welder task (Table 26) reported a high percentage (approximately 80%) of risk factors present for the elbows, forearms, and hands. Moderate percentages (approximately 50% - 65%) of risk factors were present for the neck, shoulder, upper back, low back, feet, knees and hips. A high percentage (approximately 80%) of environmental and organizational modifying factors were present as well.

IIID. SHEAR OPERATION IN THE PLATE SHOP

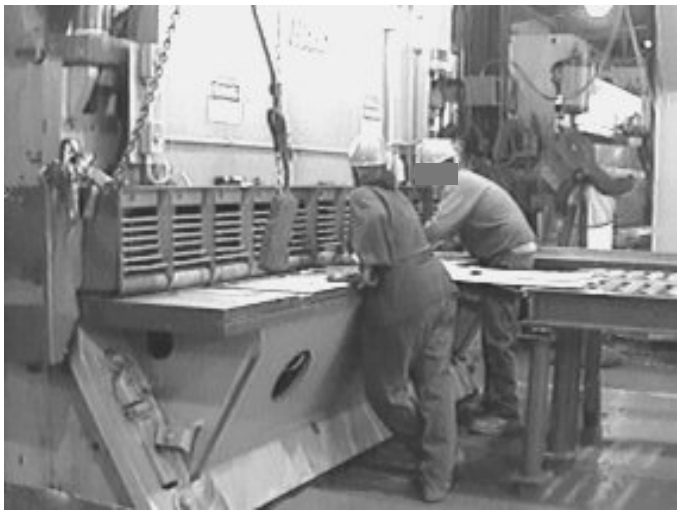

Figure 15. Shear operation in plate shop

IIID1. Injury Data

The plate shop area of the shipyard included the shear operators. The information for the shear operators could not be sorted out from the rest of the workers in the plate shop. The plate shop was first within the shipyard in the actual number of days away from work for musculoskeletal back injuries. It was also first in the actual number of days away from work for all musculoskeletal injuries. The plate shop was second within the shipyard in actual number of restricted or light duty days for musculoskeletal injuries.

IIID2. Process

The primary processes within the plate shop are to cut, size, and shape steel plate required for hulls and subassemblies using shear machines, automated plasma cutters, and manual cutting torches. The particular process flow for the shear press is as follows:

1) Raw plates are moved to pallets next to the shear by a jib crane that sits between stations.
2) Plates are moved manually from pallet to shear.

3) Cut plates are sorted at the back of the shear at ground level and lifted into carts

Figure 16. Shear operator lifting plate from back of shear

IIID3. Ergonomic Risk Factors

Shear operators often lift awkward loads from the ground-level shear chutes and material supply pallets. Contact stresses experienced by the shear operator include kneeling on the floor to get material and contact with the sharp edges of the raw or cut material.

IIID4. Ergonomic Analysis of Shear Operator in Plate Shop

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the shear operator task (Table 27), of the 21 possible responses, 8 were negative, 6 were positive, and 7 were not applicable. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the shear operator task (Table 28), a score of 2, on a scale from 1 to 4, was obtained for a number of specific subtasks. These subtasks included positioning the plate at the front of the shear, lifting and moving pieces by crane, and manually lifting pieces from the back of the shear. If the torso is twisted while lifting, this subtask response changes to a score of 4, on a 4-point scale.

The NIOSH checklist for manual materials handling consists of 14 items. When applied to the shear operator task (Table 29), 10 responses were positive and 4 negative. In this checklist, positive responses are indicative of conditions that pose a risk to the worker of developing low back pain. The higher the percentage of positive response, the greater the risk of low back pain. For the shear operator task, this percentage was 71%.

The NIOSH Lifting Equation was used to analyze the sub-task of manually picking material up from the back of the shear press. The analysis (Table 30) for this task suggests a recommended weight limit of 13.7 pounds, given the assumed posture. Given that the typical weight of the plate is about 20 pounds, it is determined that 95% of the male population and 49% of the female population can perform this task without an increased risk of low back pain.

The University of Michigan 3D Static Strength Prediction Program was used to analyze two shear operator subtasks (Table 31). Analysis of these subtasks resulted in estimated disc compression loads at the L5/S1 disc to be below the NIOSH Recommended Compression Limit of 770 pounds for both subtasks. The average estimated disc compression load was 591 pounds.

The PLIBEL checklist for the shear operator task (Table 32) reported a moderate percentage (approximately 50%) of risk factors present for the neck, shoulder, upper back, and lower back. Several environmental and organizational modifying factors were present as well.

IV. CONTROL TECHNOLOGY

Possible interventions and control technologies are mentioned briefly here. A more detailed report of possible interventions is in press.

IVA. RAKE FRAME SUBASSEMBLY POSSIBLE INTERVENTIONS

An adjustable jig (a jig top placed on a lift table) may offer a solution, and it may be that one jig can be made to fit all three rake frames. This would open more floor space and eliminate the need for the welders and shipfitter to bend. Possible problems with this approach are that some of the workers prefer the low height of the jig because the angles can be pivoted and maneuvered into place easily. Another concern is that the jig would be too high for the crane to offload, but this would not be a problem if the jig could be again lowered when unloaded. Also, there are concerns that the welders would trip over the raised rake frame, although no welds actually require the welder to be inside of the frame while welding. The only reason that they currently stand inside of the frame while welding is because the angle irons are stacked up parallel to the jig approximately 1 foot away and impede getting around the outside of the frame. This means that the stacking of the material would have to be changed too if the jig was raised, unless the frame could be rotated as it was raised, which might be possible if engine stand type lifts were used. A rotatable jig would also eliminate the need for the crane to flip the frame and also eliminate the problem of welding the frames that are stacked on the ground first. Two years ago, a number of similar changes were made in other areas of the structural shop. Coincidentally or not, the MSD incidence rate dropped dramatically from 16 in 1997 to 5 in 1998.

IVB. ANGLE IRON UNLOAD IN STEELYARD POSSIBLE INTERVENTIONS

An uneven and tilted surface on the stand may help to break the load up as it is released from the crane. Changes in how the load is slung and/or handled by the crane may also help. A simple push mechanism on the unloading table would eliminate the need for the two workers who hook and pull each angle across the table.

IVC. CONFINED SPACE WELDING ON LINE 4 HULL POSSIBLE INTERVENTIONS

Possible interventions include changing the weld process from stick to wire welding, using creeper carts that would allow the worker to roll to the back of the honeycomb section, installing automatic welding systems, and improving ventilation systems.

IVD. SHEAR OPERATION IN PLATE SHOP POSSIBLE INTERVENTIONS

The primary intervention for the plate shop shear operator is to provide adjustable lift tables for raw plates at the front of the shear and also for the shear chute at the back of the machine.

V. CONCLUSIONS AND RECOMMENDATIONS

Four work processes within a barge building operation were surveyed to determine the presence of risk factors associated with musculoskeletal disorders. The rake frame subassembly task requires workers in the shipfitter trade to maneuver long steel angle irons into position in a pattern laid out on the shop's steel floor. These long angle irons can weigh approximately 240 pounds and are slid or bounced into position between jigs welded onto the floor. Smaller angle irons and steel plates are manually placed to form cross members or corner supports. The combination of manual materials handling and awkward posture of bending the torso to place the material near floor level results in a job the can be considered high in musculoskeletal disorder risk factors. Six separate exposure assessment techniques were used to quantify the risk factors associated with this shipfitter job. A possible intervention is raising the work surface by installing a lift table to hold the jig pattern for the rake frame, thereby eliminating the bent torso for much of the task. Welders who join the individual pieces of steel also exhibit awkward postures while working near floor level. By raising the work surface, these awkward postures are minimized.

The unloading of angle iron in the steelyard was also analyzed using a number of exposure assessment techniques. The high amount of effort required to separate and flip individual pieces of long angle iron are some of the risk factors associated with this process. Possible interventions include angling the surface of the stock table to encourage the stack of angle irons to loosen when dropped by the yard crane, and automating some of the processes to eliminate the pulling of angle irons into position across the roller conveyor.

The honeycomb welder task in the manufacture of double hull sections requires the worker to enter a confined space and weld two seams between vertical supports and the bottom steel plate. This process can be improved from current conditions by changing ventilation set-ups, changing

from stick to wire welding, or by automating the welding process. This last option may be the most desirable because it removes the worker from exposure to risk factors. Otherwise, the constrained postures, exposure to contact stresses in the knees and elbows, and exposure to some welding fumes would still be present.

The shear operator in the plate shop often bends at the waist to pick up pieces of steel, either from a supply bin or from the tray at the back of the shear machine. Manually lifting the pieces of steel from near floor level results in undue stress on the back of the workers. By incorporating lift tables or tilting pallet jacks into areas both in front and behind the shear machine, one can minimize the stress on the workers' backs. Each of the interventions highlighted here for each of the four processes will be discussed in much greater detail in a forthcoming report.

It is recommended that further action be taken to mitigate the exposure to musculoskeletal risk factors within each of the identified tasks. The implementation of ergonomic interventions has been found to reduce the amount and severity of musculoskeletal disorders within the working population in various industries. It is suggested that ergonomic interventions may be considered for implementation at Jeffboat to minimize hazards in the identified job tasks.

VI. REFERENCES

Kemmlert, K. A Method Assigned for the Identification of Ergonomic Hazards – PLIBEL. Applied Ergonomics, 1995, 26(3):199-211.

Lifshitz, Y. and T. Armstrong. A Design Checklist for Control and Prediction of Cumulative Trauma Disorders in Hand Intensive Manual Jobs. Proceedings of the 30th Annual Meeting of Human Factors Society, 1986, 837-841.

Louhevaara, V. and T. Suurnäkki. OWAS: A Method for the Evaluation of Postural Load during Work. Training Publication No. 11, Institute of Occupational Health, Helsinki, Finland, 1992.

McAtamney, L. and E. N. Corlett. RULA: A Survey Method for the Investigation of Work-Related Upper Limb Disorders, Applied Ergonomics, 1993, 24(2):91-99.

Moore, J. S. and A. Garg. The Strain Index: A Proposed Method to Analyze Jobs for Risk of Distal Upper Extremity Disorders, American Industrial Hygiene Association Journal, 1995, 56:443-458.

University of Michigan Software, 3D Static Strength Prediction Program Version 4.0, 3003 State St., #2071, Ann Arbor, MI 48109-1280, Copyright 1997 The Regents of The University of Michigan.

Waters, T. R., V. Putz-Anderson, A. Garg, and L. J. Fine. Revised NIOSH Equation for the Design and Evaluation of Manual Lifting Tasks, Ergonomics, 1993, 36(7):749-776.

Waters, T. R. and V. Putz-Anderson. Manual Materials Handling, Ch. in Occupational Ergonomics: Theory and Applications, ed. by A. Bhattacharya and J. D. McGlothlin, Marcel Dekker, Inc., New York, 1996, pp. 329-349.

APPENDIX

ERGONOMIC ANALYSIS TABLES

A1. RAKE FRAME SHIPFITTERS

Table 1. Rake Frame Shipfitter Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Structural Shop	Rake Frame Shipfitting

1. **Intensity of Exertion:** An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
Somewhat Hard	10% - 29%	3	noticeable or definite effort	2	3
Hard	**30% - 49%**	**4 - 5**	**obvious effort; unchanged facial expression (*28% - 38% of observed time > = Hard)**	**3**	**6**
Very Hard	50% - 79%	6 - 7	substantial effort; changes to facial expression	4	9
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13
Intensity of Exertion Multiplier					**6**

Table 1. Rake Frame Shipfitter Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion; then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 546 (sec)/ 984 (sec) = 55% *for cycle "2 nd keel frame"	< 10%	1	0.5
	10% - 29%	2	1.0
	30% - 49%	3	1.5
	50% -79%	**4**	**2.0**
	> or = 80%	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period; then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion; then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions / Total observation time (min) = [total # of efforts for observed period, 67/ Total observed time (min) 16.39] = 4.1	< 4	1	0.5
	4 - 8	**2**	**1.0**
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**1.0**

Table 1. Rake Frame Shipfitter Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	**11 - 25 degrees**	**6 - 15 degrees**	**11 -15 degrees**	**near neutral (*estimated, no RULA done)**	**2**	**1.0**
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.0**

5. Speed of Work: An estimate of how fast the worker is working. Circle the rating on the far right after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM**	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81% - 90%	taking one's own time	2	1.0
Fair	**91% - 100%**	**normal speed of motion**	**3**	**1.0**
Fast	101% - 115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed and barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 1. Rake Frame Shipfitter Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (22 frames per day @ 20 minutes per frame-- from mgmt-- 7.3 hrs of frame cycle time @ .55 duration of exertion (See #2) = 4 hrs per day)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	**3**	**0.75**
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below; then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
6.0 X	**2.0 X**	**1.0 x**	**1.0 x**	**1.0 x**	**0.75**		**9.0**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity (DUE) injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 2. Rake Frame Shipfitter UE CTD Checklist

Michigan Checklist for Upper Extremity (UE) Cumulative Trauma Disorders (CTD)
(Lifshitz and Armstrong, 1986)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Structural Shop	Rake Frame Shipfitting

Risk Factors	**No***	**Yes**
1**. Physical Stress**		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10 lbs.) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	n/a	n/a
3.3 Can the job be done without deviating the wrist from side to side?		Y
3.4 Can the tool be used without deviating the wrist from side to side?		Y
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	n/a	n/a
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9 lbs.)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	**8**	**7**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 3. Rake Frame Shipfitter OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date	**Facility**			**Area/Shop**			**Task**		
11/9/99	Jeffboat			Structural Shop			Rake Frame Shipfitting		
Risk Factor	**Work Phase 1** **Place Angle Irons**	**Work Phase 2** **Clamp / Un-clamp**	**Work Phase 3** **Hammer Wedges**	**Work Phase 4** **Deslag**	**Work Phase 5** **Stage Angles**	**Work Phase 6** **Rest**	**Work Phase 7** **Un-defined**	**Work Phase 8** **Torch Cut**	**Work Phase 9** **Place Angle Pieces**
TOTAL Combination Posture Score	**3, 4**	**2, 4**	**2, 4**	**2, 4**	**3, 4**	**1**	**1**	**2**	**2, 3, 4**
Common Posture Combinations (collapsed across work phases)									
Back	4	1	2	4	2	2	1		
Arms	1	1	1	1	1	1	1		
Legs	7	1	4	4	7	4	2		
Posture Repetition (% of working time)	51	45	4	51*	51*	55*	4*		
Back % of Working Time Score	3	1	1	3	2	2	1		
Arms % of Working Time Score	1	1	1	1	1	1	1		
Legs % of Working Time Score	1	1	1	3	1	3	1		

ACTION CATEGORIES:
1 = No corrective measures
2 = Corrective measures in near future
3 = Corrective measures as soon as possible
4 = Corrective measures immediately

Table 3. Rake Frame Shipfitter OWAS (continued)

Risk Factor	**Work Phase 1** **Place Angle Irons**	**Work Phase 2** **Clamp/ un-clamp**	**Work Phase 3** **Hammer Wedges**	**Work Phase 4** **Deslag**	**Work Phase 5** **Stage Angles**	**Work Phase 6** **Rest**	**Work Phase 7** **Un-defined**	**Work Phase 8** **Torch Cut**	**Work Phase 9** **Place Angle Pieces**
Posture									
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2,4	2,4	2,4	2,4	2,4	1	1	2	2,4
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	7	4, 7	4,7	4,7	4,7	1,2	1,2	4	4,7
Load/ Use of Force									
1 = weight or force needed is = or <10 kg (<22 lb)	3	1	1	1	3	1	1	1	2
2 = weight or force > 10 but < 20kg (>22lb < 44 lb)									
3 = weight or force > 20 kg (>44 lb)									
Phase Repetition									
% of working time: (0,10,20,30,40,50,60,70,80,90,100)	10	18	7	13	1	5	40	4	2

Table 4. Rake Frame Shipfitter NIOSH Manual Materials Handling Checklist

NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling
(Waters and Putz-Anderson, 1996)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Structural Shop	Rake Frame Shipfitting

RISK FACTORS	**YES**	**NO**
General		
1.1 Does the load handled exceed 50 lb?	Y (usually)	
1.2 Is the object difficult to bring close to the body because of its size, bulk, or shape?	Y	
1.3 Is the load hard to handle because it lacks handles or cutouts for handles, or does it have slippery surfaces or sharp edges?	Y	
1.4 Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?	Y (fixtures in way)	
1.5 Does the task require fast movement, such as throwing, swinging, or rapid walking?		N
1.6 Does the task require stressful body postures such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?	Y (extreme lumbar flexion)	
1.7 Is most of the load handled by only one hand, arm, or shoulder?		N
1.8 Does the task require working in environmental hazards, such as extreme temperatures, noise, vibration, lighting, or airborne contamination?	Y (welding, machinery in proximity,)	
1.9 Does the task require working in a confined area?		N
Specific		
2.1 Does the lifting frequency exceed 5 lifts per minute (LPM)?		N (LPM = 0.67 over total cycle time, but lifts are performed in rapid succession at a frequency of 2 LPM)
2.2 Does the vertical lifting distance exceed 3 feet?		N (seldom)
2.3 Do carries last longer than 1 minute?		N
2.4 Do tasks which require large sustained pushing or pulling forces exceed 30 seconds duration?		N (usually < = 10)
2.5 Do extended reach static holding tasks exceed 1 minute?		N
TOTAL	**6 (43%)**	**8 (57%)**

* "YES" responses are indicative of conditions that pose a risk of developing low back pain; the larger the percentage of"YES" responses, the greater the risk.

Table 5. Rake Frame Shipfitter 3D Static Strength Prediction Program

3D Static Strength Prediction Program
(University of Michigan, 1997)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Structural Shop	Rake Frame Shipfitting

Work Elements: Manual Placement of Angle Iron Rake Frame Components	**Disc Compression (lb) @ L5/S1** (Note: NIOSH Recommended Compression Limit (RCL) is 770 lb)
Angle RF2 weighs 133 lb; lifts one end off stack pivots angle, then drops into place; 33.25 lb per arm (frame #3960)	**1389** (middle of lift)
Curved angle RF1 weighs 246 lb; lifts one end, pivots into place, lowers load with control; 123 lb lifted, 61.5 lb per arm (frames #4320, #4350)	**857** (middle of lift) **1531** (end of lift)
Angle RF3 weighs 125 lb; lifts one end off stack, and pivots into place, lowers load, then drops into place; lifts @ 62.5 lb or 31.25 lb per arm (frames #6030, #6060, #6119)	**926** (beginning of lift) 597 (middle of lift) **1021** (end of lift)
Angle RF4 weighs 47 lbs; shipfitter lifts one end with one hand; lifts 23.50 lb by right arm (frame #7920), then lowers entire angle; lifts 23.50 lb per arm (frame #7980)	**854** (beginning of lift) 691 (middle of lift)
Angle RT-3 weighs 65 lb; lifts one end with one hand off stack; 32.50 lb by right arm (frame #8550). Then, uses two arms to carry angle into place; 32.50 lb per arm (frame #8700)	**1009** (beginning of lift) 551 (middle of lift)
Angle RT-1 weighs 95 lb; lifts one end with one hand off stack before using two to drag it into place; 47.50 lb by right arm for initial lift (frame #9810)	**926** (beginning of lift)
Angle RT-2 weighs 70 lb; lifts one end with one hand off stack before using two hands to drag it into place; 35 lb by right arm (frame #10980)	709 (beginning of lift)
Angle RF-5 weighs 52 lb; lifts one end with both hands off stack before using two to lift it into place; 26 lb lifted per arm (frame #11150, 11700)	**1187** (beginning of lift) 668 (middle of lift)

Table 6. Rake Frame Shipfitter PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Structural Shop	Rake Frame Shipfitting

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions, or
2) Answer questions, score potential body regions for injury risk.

Musculoskeletal Risk Factor Questions	**Body Regions**				
	Neck, Shoulder, and Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	N				N
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? For example, ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	Y				Y

Table 6. Rake Frame Shipfitter PLIBEL (continued)

10: Is repeated or sustained work performed when the neck is:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Notice factors of importance as:					
a) periods of repetitive lifting	Y				Y
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing, or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work with forearm and hand done with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		N			
d) switches or keyboards?		N			

Table 6. Rake Frame Shipfitter PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**20**	**9**	**3**	**3**	**15**
PERCENTAGE	**76.9**	**81.8**	**37.5**	**37.5**	**71.4**

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores.	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y
20: Is the job performed under time demands or psychological stress?	Y
21: Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	N
b) heat	Y
c) draft	Y
d) noise	Y
e) troublesome visual conditions	Y
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	**6**
PERCENTAGE	**60.0**

A2. RAKE FRAME WELDERS

Table 7. Rake Frame Welders RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Structural Shop	Rake Frame Welding

RULA Component	**Frame # 54600**		**Frame# 62130**		**Frame # 66600**		**Frame # 68580**		**Composite (frames 53820 -- 73290)**	
	Specific	**RULA Score**	**Specific**	**RULA Score**	**Specific**	**RULA Score**	**Specific**	**RULA Score**	**Specific**	**RULA Score**
Shoulder Extension/ Flexion	m flex	3	sl flex	2	sl flex	2	sl flex	2	sl flex (53%)	2
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		-1		-1		-1		-1		-1
Elbow Extension/ Flexion	neut	2	ext	1	ext	1	flex	2	ext (61%)	1
Shoulder Abduction/ Adduction	add	1	add	1	add	1	mod abd	1	neut (50%)	0
Shoulder Lateral/ Medial	neut	0	m med	1	m med	1	m med	1	neut (51%)	0
Wrist Extension/ Flexion	ext	2	ext	2	ext	2	ext	2	ext (64%)	2
Wrist Deviation [Wrist Bent from Midline (+1)]	ulnar	1	rad	1	neut	0	ulnar	1	neut (33%)	0
Wrist Bent from Midline (+1) (taken care of by deviation)		0		0		0		0		0
Wrist Twist (+1) In mid range (+2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Arm and Wrist Force/Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		2		2		2
Neck Extension/ Flexion		3		3		3		3		3

Table 7. Rake Frame Welders RULA (continued)

Neck Twist (+1)		0		0		0		0		0
Neck Side Bend (+1)		0		0		0		0		0
Trunk Extension/ Flexion	hyp flex	4	sl flex	2	hyp flex	4	hyp flex	4	hyp flex 100%	4
Trunk Twist (+1)		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		2		3		3		3
Total RULA Score	**7**		**7**		**7**		**7**		**7**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 8. Rake Frame Welder Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Structural Shop	Rake Frame Welding

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg's Cr-10 scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat Hard	**10% - 29%**	**3**	**noticeable or definite effort (84% of observed time)**	**2**	**3.0**
Hard	30% - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50% - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 8. Rake Frame Welders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period; then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion; then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0.

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) Total observation time (sec) = 100 x 2365(sec)/ 3593 (sec) = 66%, but welding is very static	< 10%	1	0.5
	10% - 29%	2	1.0
	30% - 49%	3	1.5
	50% -79%	**4**	**2.0**
	> or = 80%	5	3
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period; then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0.

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions Total observation time (min) *welding is a very static task	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	**5**	**3.0**
Efforts per Minute Multiplier			**3.0**

Table 8. Rake Frame Welders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral (*estimated, based on RULAs performed)**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Compared to MTM**	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81% - 90%	taking one's own time	2	1.0
Fair	**91% - 100%**	**normal speed of motion**	**3**	**1.0**
Fast	101% - 115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 8. Rake Frame Welders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 4-8 hrs)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	**4**	**1.00**
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below; then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
3.0 X	**2.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**1.0**		**27.0**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
– SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
– SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
– SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
– SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 9. Rake Frame Welder UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Structural Shop	Rake Frame Welding

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lb) of force?		Y
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?		Y
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N (static)	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y (handle)
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lb)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**10**	**12**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 10. Rake Frame Welder OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date	**Facility**		**Area/Shop**		**Task**		
11/9/99	Jeffboat		Structural Shop		Rake Frame Welding		
Risk Factor	**Work Phase 1** welding inside frame at pos. 1	**Work Phase 2** welding straddle frame at pos. 1	**Work Phase 3** De-slagging	**Work Phase 4** welding outside frame at pos. 2	**Work Phase 5** undefined	**Work Phase 6** resting	**Work Phase 7** guiding crane lowering frame
TOTAL Combination Posture Score	**2**	**2**	**2**	**2**	**1**	**1**	**1**
Common Posture Combinations (collapsed across work phases)							
Back	2	1	2	2	1		
Arms	1	1	1	1	1		
Legs	1	7	7	4	1		
Posture Repetition (% of working time)	16	8	3	55	29		
Back % of Working Time Score	2	1	1	2	1		
Arms % of Working Time Score	1	1	1	1	1		
Legs % of Working Time Score	1	1	1	3	1		
ACTION CATEGORIES: 1 = No corrective measures 2 = Corrective measures in near future 3 = Corrective measures as soon as possible 4 = Corrective measures immediately							

Table 10. Rake Frame Welder OWAS (continued)

Risk Factor	**Work Phase 1** **welding inside frame at pos. 1**	**Work Phase 2** **welding straddle frame at pos. 1**	**Work Phase 3** **De-slagging**	**Work Phase 4** **welding outside frame at pos. 2**	**Work Phase 5** **undefined**	**Work Phase 6** **resting**	**Work Phase 7** **guiding crane lowering frame**
Posture							
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	2	2	1	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1,4	1,4	7	4,7	7	1	7
Load/ Use of Force							
1 = weight or force needed is = or <10 kg (<22 lb)	1	1	1	1	1	1	1
2 = weight or force > 10 but < 20kg (>22 lb < 44 lb)							
3 = weight or force > 20 kg (>44 lb)							
Phase Repetition							
% of working time: (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	31	10	3	19	5	29	3

Table 11. Rake Frame Welder PLIBEL

PLIBEL Checklist
Kemmlert (1995)

Date	Facility	Area/Shop	Task
11/9/99	Jeffboat	Structural Shop	Rake Frame Welding

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions, or
2) Answer questions, score potential body regions for injury risk.

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	N	N	N	N	N
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 11. Rake Frame Welder PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	Y				
17: Is repeated work with forearm and hand performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 11. Rake Frame Welder PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	**Elbows, Forearms, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**13**	**6**	**1**	**1**	**6**
PERCENTAGE	**50.0**	**54.5**	**12.5**	**12.5**	**28.6**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y				
20: Is the job performed under time demands or psychological stress?	Y				
21: Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	**6**				
PERCENTAGE	**60.0**				

A3. GATOR BAR WORKER IN STEELYARD

Table 12. Gator Bar Worker RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date	Facility	Area/Shop	Task
11/9/99	Jeffboat	Steelyard	Angle Iron Separation

RULA Component	Frame # 25650		Frame # 26310		Frame #27060		Frame # 27510		Composite (frames 24660 - 27330)	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	mod flex	3	sl flex	2	sl flex (68%)	2
Shoulder is Raised (+1)		0		1		1		1		1
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	flex	2	ext	1	flex	2	ext	1	flex (41%)	2
Shoulder Abduction/ Adduction	m abd	1	neut	0	m abd	1	m abd	1	neut (59%)	0
Shoulder Lateral/ Medial	m med	1	neut	0	lat	1	m med	1	neut (47%)	0
Wrist Extension/ Flexion	ext	2	ext	2	ext	2	ext	2	ext (62%)	2
Wrist Deviation	ulnar	1	ulnar	1	rad	1	ulnar	1	ulnar (53%)	1
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Arm and Wrist Force/Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		3		3		3		3
Neck Extension/ Flexion		2		2		2		2		2
Neck Twist (+1)		1		0		1		0		0
Neck Side Bend (+1)		0		0		0		0		0
Trunk Twist (+1)		1		0		1		0		0

Table 12: Gator Bar Worker RULA (continued)

Trunk Extension/ Flexion	sl flex	2	sl flex	2	sl flex	2	sl flex	2	sl flex (64%)	2
Trunk Twist (+1)		1		0		1		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e., held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		3		3		3		3
Total RULA Score	**7**		**7**		**7**		**7**		**7**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 13. Gator Bar Worker Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Steelyard	Angle Iron Separation

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS (percentage of maximal strength)**	**Borg Scale (Compare to Borg Cr-10 Scale)**	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat Hard	10% - 29%	3	noticeable or definite effort	2	3.0
Hard	30% - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	**50% - 79%**	**6 - 7**	**substantial effort; changes to facial expression**	**4**	**9.0**
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**9.0**

Table 13. Gator Bar Worker Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period; then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion; then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0.

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion	< 10%	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	**10% - 29%**	**2**	**1.0**
	30% - 49%	3	1.5
	50% -79%	4	2.0
	> or = 80%	5	3.0
Duration of Exertion Multiplier			**1.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period; then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion; then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0.

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute	< 4	1	0.5
= number of exertions / total observation time (min)	4 - 8	2	1.0
	9 -14	**3**	**1.5**
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**1.5**

Table 13. Gator Bar Worker Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	**41 - 55 degrees (extension 52% of load task time)**	**31 - 50 degrees (flexion 11% of load task time)**	**21 -25 degrees (ulnar deviation 53% of load task time)**	**marked deviation**	**4**	**2.0**
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**2.0**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM**	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81% - 90%	taking one's own time	2	1.0
Fair	**91% - 100%**	**normal speed of motion**	**3**	**1.0**
Fast	101% - 115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 13. Gator Bar Worker Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 1 - 2 hrs)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	**2**	**0.50**
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.50**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below; then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
9.0 X	**1.0 X**	**1.5 X**	**2.0 X**	**1.0 X**	**0.50**		**13.5**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 14. Gator Bar Worker UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Steelyard	Angle Iron Separation

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10 lb) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	*Not measured*	*Not measured*
6.3 Is the handle of the tool made from material other than metal?	N	
6.4 Is the weight of the tool below 4 kg (9 lb)?	N (12.2 lb)	
6.5 Is the tool suspended?	N	
TOTAL	**15 (71%)**	**6 (29%)**

*"No" responses are indicative of conditions associated with the risk of CTD's

Table 15. Gator Bar Worker OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Steelyard	Angle Iron Separation

Risk Factor	**Work Phase1** **Wait for Crane**	**Work Phase 2** **Crane lowers load**	**Work Phase 3** **Unstrap load (and cutting binding)**	**Work Phase 4** **Using pry end of bar to separate angles**	**Work Phase 5** **Using pry end to lever angle over**	**Work Phase 6** **Using jaw end of bar to separate angles**	**Work Phase 7** **Using jaw end to flip angle over**	**Work Phase 8** **Move load off con-veyor**	**Work Phase 9** **Crane moves excess angles**
TOTAL Combination Posture Score	**1**	**1**	**1**	**4**	**4**	**4**	**2**	**1**	**1**
Common Posture Combinations (collapsed across work phases)									
Back	1	2	2	1					
Arms	1	3	3	3					
Legs	2	2	7	2					
Posture Repetition (% of working time)	42	19	19	1					
Back % of Working Time Score	1	3	4	1					
Arms % of Working Time Score	1	1	1	1					
Legs % of Working Time Score	1	1	1	1					

ACTION CATEGORIES:
1 = No corrective measures
2 = Corrective measures in near future
3 = Corrective measures as soon as possible
4 = Corrective measures immediately

Table 15. Gator Bar Workers OWAS (continued)

Risk Factor	**Work Phase1** **Wait for crane**	**Work Phase2** **Crane lowers load**	**Work Phase 3** **Unstrap load (and cutting binding)**	**Work Phase 4** **Using pry end of bar to separate angles**	**Work Phase 5** **Using pry end to lever angle over**	**Work Phase 6** **Using jaw end of bar to separate angles**	**Work Phase 7** **Using jaw end to flip angle over**	**Work Phase8** **Move load off con-veyor**	**Work Phase9** **Crane moves excess angles**
Posture									
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	1	2	2	2	1*	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	3	3	3	3	3	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2	2,7	2,7	2,7	2,7	2,7	2	2
Load/ Use of Force									
1 = weight or force needed is = or <10 kg (<22 lb)	1	1	1	3*	3*	3*	3*	1	1
2 = weight or force > 10 but < 20kg (>22 lb < 44 lb)									
3 = weight or force > 20 kg (>44 lb)									
Phase Repetition									
% of working time: (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	16	05	11	07	07	05	01	20	01

Table 16. Gator Bar Worker PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date	Facility	Area/Shop	Task
11/9/99	Jeffboat	Steelyard	Angle Iron Separation

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions.
2) Answer questions, score potential body regions for injury risk.

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	Y				Y

Table 16. Gator Bar Worker PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work with forearm and hand performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 16. Gator Bar Worker PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	**Elbows, Forearms, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**15**	**9**	**3**	**3**	**11**
PERCENTAGE	**57.7**	**81.8**	**37.5**	**37.5**	**52.4**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores.					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y				
20: Is the job performed under time demands or psychological stress?	Y				
21:Can the work have unusual or expected situations?	Y				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	**8**				
PERCENTAGE	**80.0**				

A3. GATOR BAR HELPER IN STEELYARD

Table 17. Gator Bar Helper RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Steelyard	Flip and Drag Angle Iron

RULA Component	Frame # 25200		Frame # 25590		Frame # 25920		Frame # 26610		Composite (# 24660 - 27330)	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	mod flex	3	mod flex	3	hyp flex	4	sl flex	2	sl flex (35%)	2
Shoulder is Raised (+1)		0		0		1		0		0
Upper Arm Abducted (+1)		0		1		0		1		1
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	ext	1	neut	2	ext	1	ext (60%)	1
Shoulder Abduction/ Adduction	add	1	m abd	1	add	1	neut	0	m abd (36%)	1
Shoulder Lateral/ Medial	m med	1	lat	1	m med	1	lat	1	lat (45%)	1
Wrist Extension/ Flexion	ext	2	ext	2	ext	2	flex	2	flex (49%)	2
Wrist Deviation	ulnar	1	ulnar	1	rad	1	ulnar	1	ulnar (45%)	1
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (i.e., held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Arm and Wrist Force/Load Score Load less than 2 kg (int.): (+0) If 2kg to 10 kg (int.): (+1) If 2kg to 10 kg (static or rep.): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		2		2		2
Neck Extension/ Flexion		2		2		2		2		2
Neck Twist (+1)		1		1		0		1		1
Neck Side Bend (+1)		0		0		0		0		0
Trunk Extension/Flexion	sl flex	2	sl flex	2	sl flex	2	neut	1	sl flex (50%)	2

Table 17. Steelyard Helper RULA (continued)

Trunk Twist (+1)		1		0		1		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e., held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		2		2		2
Total RULA Score	**7**		**7**		**7**		**6**		**7**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 18. Steelyard Helper Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Steelyard	Flip and Drag Angle Iron

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat Hard	**10% - 29%**	**3**	**noticeable or definite effort (*76% of observed effort time)**	**2**	**3.0**
Hard	30% - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50% - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 18. Steelyard Helper Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period; then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion; then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0.

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion	< 10%	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10% - 29%	2	1.0
	30% - 49%	**3**	**1.5**
	505 - 795	4	2.0
	> or = 80%	5	3.0
Duration of Exertion Multiplier			**1.5**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period; then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion; then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0.

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute	< 4	1	0.5
= number of exertions / total observation time (min)	**4 - 8**	**2**	**1.0**
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**1.0**

Table 18. Steelyard Helper Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	**41 - 55 degrees (extension 13% of load task time)**	**31 - 50 degrees (flexion 49% of load task time)**	**21 -25 degrees (ulnar deviation 45% of load task time)**	**marked deviation**	**4**	**2.0**
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**2.0**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Compared to MTM**	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81% - 90%	taking one's own time	2	1.0
Fair	**91% - 100%**	**normal speed of motion**	**3**	**1.0**
Fast	101% - 115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 18. Steelyard Helper Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 2-4 hrs)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	**3**	**0.75**
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below; then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
3.0 X	**1.5 X**	**1.5 X**	**2.0 X**	**1.0 X**	**0.75**		**10.1**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 19. Steelyard Helper UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Steelyard	Flip and Drag Angle Iron

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10 lb) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	Not Measured	Not Measured
6.3 Is the handle of the tool made from material other than metal?	N	
6.4 Is the weight of the tool below 4 kg (9 lb)?	N (12.2 lb)	
6.5 Is the tool suspended?	N	
TOTAL	**14 (67%)**	**7 (33%)**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 20. Gator Bar Worker OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date	**Facility**		**Area/Shop**		**Task**	
11/9/99	Jeffboat		Steelyard		Flip and Drag Angle Iron	
Risk Factor	**Work Phase 1** **Waiting for crane**	**Work Phase 2** **Crane lowering load**	**Work Phase 3** **Unstrap-ping load (and cutting binding)**	**Work Phase 4** **Using jaw end of bar to flip angle over on table**	**Work Phase 5** **Dragging angle across table with hand**	**Work Phase 6** **Standing, waiting**
TOTAL Combination Posture Score	**1**	**1**	**1**	**3**	**2 , 3**	**1**
Common Posture Combinations (collapsed across work phases)						
Back	1	1	2, 4	2, 4		
Arms	1	3	3	1		
Legs	2	2, 7	2, 7	2, 7		
Posture Repetition (% of working time)	21	11	8	1		
Back % of Working Time Score	1	1	3, 3	2, 3		
Arms % of Working Time Score	1	1	1	1		
Legs % of Working Time Score	1	1	1	1		
ACTION CATEGORIES: 1 = No corrective measures 2 = Corrective measures in near future 3 = Corrective measures as soon as possible 4 = Corrective measures immediately						

Table 20. Steelyard Helper OWAS (continued)

Risk Factor	**Work Phase1** **Waiting for crane**	**Work Phase 2** **Crane lowering load**	**Work Phase 3** **Unstrapping load (and cutting binding)**	**Work Phase 4** **Using jaw end of bar to flip angle over on table**	**Work Phase 5** **Dragging angle across table with hand**	**Work Phase 6** **Standing waiting**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	1	2,4	2,4	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	3	3	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2	2,7	2,7	2,7	2,7
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22 lb)	1	1	1	2	2	2
2 = weight or force > 10 but < 20kg (>22 lb < 44 lb)						
3 = weight or force > 20 kg (>44 lb)						
Phase Repetition						
% of working time (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	16	52	11	08	22	01

Table 21. Steelyard Helper PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date	Facility	Area/Shop	Task
11/9/99	Jeffboat	Steelyard	Flip and Drag Angle Iron

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions.
2) Answer questions, score potential body regions for injury risk.

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	N				N
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc.			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N

Table 21. Steelyard Helper PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work with forearm and hand performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 21. Steelyard Helpers PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	**Elbows, Forearms, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**11**	**8**	**2**	**2**	**7**
PERCENTAGE	**42.3**	**72.7**	**25.0**	**25.0**	**33.3**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y				
20: Is the job performed under time demands or psychological stress?	Y				
21: Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	**6**				
PERCENTAGE	**60.0**				

A5. HONEYCOMB WELDER

Table 22. Honeycomb Welder RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Weld School	Simulated Honeycomb Weld Task

RULA Component	**Frame # 1140**		**Frame # 6900**		**Frame# 10110**		**Frame # 12450**		**Composite** (frames 24660 - 276 30)	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	sl flex	2	hyp flex	4	sl flex	2	sl flex	2	sl flex (78%)	2
Shoulder is Raised (+1)		1		0		0		0		0
Upper Arm Abducted (+1)		1		0		0		0		0
Arm supported, leaning (-1)		0		0		-1		0		0
Elbow Extension/ Flexion	flex	2	neut	2	flex	2	flex	2	flex (75%)	2
Shoulder Abduction/ Adduction	m abd	1	neut	0	add	1	addt	0	add (35%)	1
Shoulder Lateral/ Medial	m med	1	m med	1	m med	1	m med	1	m med (83%)	1
Wrist Extension/ Flexion	ext	2	ext	2	ext	2	ext	2	extx (37%)	2
Wrist Deviation (Wrist Bent from Midline [+1])	ulnar	1	ulnar	1	ulnar	1	ulnar	1	ulnar (51%)	1
Wrist Bent from Midline (+1) (taken care of by deviation)		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (i.e., held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Arm and Wrist Force/Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		2		2		2

Table 22. Honeycomb Welder RULA (continued)

Neck Extension/ Flexion		3		3		3		3		3
Neck Twist (+1)		1		1		0		0		1
Neck Side-Bent (+1)		1		0		0		0		0
Trunk Extension/Flexion	hyp flex	4	hyp flex	4	hyp flex	4	hyp flex	4	hyp flex 100%	4
Trunk Twist (+1)		1		0		0		0		0
Trunk Side Bend (+1)		1		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e., held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		2		2		2
Total RULA Score	**7**		**7**		**7**		**6**		**7**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 23. Honeycomb Welder Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Weld School	Simulated Honeycomb Weld Task

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat Hard	**10% - 29%**	**3**	**noticeable or definite effort**	**2**	**3.0**
Hard	30% - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50% - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 23. Honeycomb Welder Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period; then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion; then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0.

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion	< 10%	1	0.5
= 100 x duration of all exertions (sec) / Total observation time (sec)	10% - 29%	2	1.0
	30% - 49%	3	1.5
= 100 x 1310 (sec)/ 1677 (sec) = 78%	**50% -79%**	**4**	**2.0**
	> or = 80%	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period; then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion; then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0.

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute	< 4	1	0.5
= number of exertions / total observation time (min)	4 - 8	2	1.0
	9 -14	3	1.5
= 61/ 28 = 2.2	15 -19	4	2.0
= but very static, so 3.0	**> or = 20**	**5**	**3.0**
Efforts per Minute Multiplier			**3.0**

Table 23. Honeycomb Welder Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees (37% of time)**	**16 - 30 degrees (1% of time)**	**16 - 20 degrees (51% of time)**	**non-neutral**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Compared to MTM** (observed pace is divided by MTM's predicted pace and expressed as %)	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81% - 90%	"taking one's own time"	2	1.0
Fair	**91% - 100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101% - 115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 23. Honeycomb Welder Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below; then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 2-4 hrs)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	**4**	**1.00**
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below; then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
3.0 X	**2.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**1.0**		**27**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 24. Honeycomb Welder UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Weld School	Simulated Honeycomb Weld Task

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10 lb) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?		Y
3.4 Can the tool be used without deviating the wrist from side to side?		Y
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N	
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9 lb)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**10 (48%)**	**11 (52%)**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 25. Honeycomb Welder OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Weld School	Simulated Honeycomb Weld Task

Risk Factor	**Work Phase1: Arctime**	**Work Phase 2: Deslagging**	**Work Phase 3 Change Sticks**	**Work Phase 4 Get New Sticks**	**Work Phase 5 Move to new Honeycomb**
TOTAL Combination Posture Score		**4 or 2**	**4 or 2**	**1**	**1**
Common Posture Combinations (collapsed across work phases)					
Back	4	1	2		
Arms	1	1	1		
Legs	6	7	6		
Posture Repetition (% of working time)	69	10	69*		
Back % of Working Time Score	3	1	2		
Arms % of Working Time Score	1	1	1		
Legs % of Working Time Score	3	1	3		

ACTION CATEGORIES:
1 = No corrective measures
2 = Corrective measures in near future
3 = Corrective measures as soon as possible
4 = Corrective measures immediately

Table 25. Honeycomb Welder OWAS (continued)

Risk Factor	**Work Phase1:** **Arctime**	**Work Phase 2:** **Deslagging**	**Work Phase 3** **Change Sticks**	**Work Phase 4** **Get New Sticks**	**Work Phase 5** **Move to new Honeycomb**
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2, 4	2,4	2,4	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	6	6	6	7	7
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22 lb)	1	1	1	1	1
2 = weight or force > 10 but < 20kg (>22 lb < 44 lb)					
3 = weight or force > 20 kg (>44 lb)					
Phase Repetition					
% of working time (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	56	12	> 1	6	4

Table 26. Honeycomb Welders PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date	Facility	Area/Shop	Task
11/9/99	Jeffboat	Weld School	Simulated Honeycomb Weld Task

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions.
2) Answer questions, score potential body regions for injury risk.

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	N				N
5: Is the working chair poorly designed or incorrectly adjusted?	N				N
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step, etc.			Y	Y	Y
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	Y				Y

Table 26. Honeycomb Welder PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	Y				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 26. Honeycomb Welder PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	**Elbows, Forearms, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**17**	**9**	**5**	**5**	**11**
PERCENTAGE	**65.4**	**81.8**	**62.5**	**62.5**	**52.4**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores.					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y				
20: Is the job performed under time demands or psychological stress?	Y				
21:Can the work have unusual or expected situations?	Y				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	**8**				
PERCENTAGE	**80.0**				

A6. SHEAR OPERATOR

Table 27. Shear Operator UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Plate Shop	Shear Operator

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10 lb) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	n/a	n/a
3.3 Can the job be done without deviating the wrist from side to side?		Y
3.4 Can the tool be used without deviating the wrist from side to side?		Y
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	n/a	n/a
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9 lb)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	**8 (57%)**	**6 (43%)**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 28. Shear Operator OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Plate Shop	Shear Operator

Risk Factor	**Work Phase 1** **Activate shear**	**Work Phase 2** **Position plate (work-piece) in front of shear, measure piece**	**Work Phase 3** **Guide over-head jib crane to back of shear to move plate**	**Work Phase 4** **Attach crane clamp to plate (work-piece)**	**Work Phase 5** **Lift, move workpiece from back of shear to front with crane**	**Work Phase 6** **Manual pick up piece from shear slope (low shin-level)**	**Work Phase 7** **Manual carry work-piece from shear back to front**	**Work Phase 8** **Un-defined**	**Work Phase 9** **Walk back, forth from shear front, back (no load)**
TOTAL Combination Posture Score	**1**	**2**	**1**	**1**	**2**	**2,4**	**1**	**1**	**1**
Common Posture Combinations (collapsed across work phases)									
Back	1	2	1	2	2	4	1		
Arms	3	1	1	1	1	1	1		
Legs	2	2	7	7	4	4	2		
Posture Repetition (% of working time)	5	20	5	4	<1	<1	66		
Back % of Working Time Score	1	1	1	1	1	1	1		
Arms % of Working Time Score	1	1	1	1	1	1	1		
Legs % of Working Time Score	1	1	1	1	1	1	1		

ACTION CATEGORIES:
1 = No corrective measures
2 = Corrective measures in near future
3 = Corrective measures as soon as possible
4 = Corrective measures immediately

Table 28. Shear Operator OWAS (continued)

Risk Factor	**Work Phase 1** **Activate shear**	**Work Phase 2** **Position plate in front of shear, measure piece**	**Work Phase 3** **Guide overhead jib crane to back of shear to move plate**	**Work Phase 4** **Attach crane clamp to plate (work-piece)**	**Work Phase 5** **Lift, move work-piece from back of shear to front with crane**	**Work Phase 6** **Manual pick up piece from shear slope (low shin-level)**	**Work Phase 7** **Manual carry piece from shear back to front**	**Work Phase 8** **Un-defined**	**Work Phase 9** **Walk back, forth from shear front, back (no load)**
Posture									
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	2	1	1	2	2,4	1	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	3	1	1	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2,4	7	7	7	4	7	2	7
Load/ Use of Force									
1 = weight or force needed is = or <10 kg (<22 lb)	1	1	1	1	1	1	1	1	1
2 = weight or force > 10 but < 20 kg (>22 lb < 44 lb)									
3 = weight or force > 20 kg (>44 lb)									
Phase Repetition									
% of working time: (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	5	20	1	<1	4	<1	2	66	<1

Table 29. Shear Operator NIOSH Manual Materials Handling Checklist

NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling
(Waters and Putz-Anderson, 1996)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Plate Shop	Shear Operator

RISK FACTORS	**YES**	**NO**
General		
1.1 Does the load handled exceed 50 lb?		N
1.2 Is the object difficult to bring close to the body because of its size, bulk, or shape?	Y	
1.3 Is the load hard to handle because it lacks handles or cutouts for handles, or does it have slippery surfaces or sharp edges?	Y	
1.4 Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?		N
1.5 Does the task require fast movement, such as throwing, swinging, or rapid walking?		N
1.6 Does the task require stressful body postures, such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?	Y (extreme lumbar flexion)	
1.7 Is most of the load handled by only one hand, arm, or shoulder?		N
1.8 Does the task require working in environmental hazards, such as extreme temperatures, noise, vibration, lighting, or airborne contamination?		N
1.9 Does the task require working in a confined area?		N
Specific		
2.1 Does the lifting frequency exceed 5 lifts per minute (LPM)?		N (LPM = 0.12 over total observed time of 25 minutes)
2.2 Does the vertical lifting distance exceed 3 feet?	Y	
2.3 Do carries last longer than 1 minute?		N
2.4 Do tasks which require large sustained pushing or pulling forces exceed 30 seconds duration?		N
2.5 Do extended reach static holding tasks exceed 1 minute?		N
TOTAL	**4 (29%)**	**10(71%)**

* "YES" responses are indicative of conditions that pose a risk of developing low back pain; the larger the percentage of "YES" responses, the greater the risk.

Table 30. Shear Operator NIOSH Lifting Equation Analysis

NIOSH Lifting Equation
(Waters, Putz-Anderson, Garg, and Fine, 1993)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Plate Shop	Shear Operator

Duration: 1 hour	**Average Object Weight: 20 pounds**	**Maximum Object Weight: 51 pounds**
ORIGIN VARIABLE	**ORIGIN VALUE**	**ORIGIN MULTIPLIER**
Horizontal Location, H	24 inches	0.42
Vertical Location, V	5 inches	0.81
Travel Distance, D	31 inches	0.88
Asymmetric Angle, A	0 degrees	1.00
Frequency, F	0.16 lifts/minute	1.00
Hand to Object Coupling, C	Poor	0.90
DESTINATION VARIABLE	**DESTINATION VALUE**	**DESTINATION MULTIPLIER**
Horizontal Location, H	12 inches	0.83
Vertical Location, V	36 inches	0.96
Travel Distance, D	31 inches	0.88
Asymmetric Angle, A	0 degrees	1.00
Frequency, F	0.16 lifts/minute	1.00
Hand to Object Coupling, C	Poor	0.90
RESULTS	**ORIGIN**	**DESTINATION**
Recommended Weight Limit (RWL)	13.7 pounds	32.2 pounds
Lifting Index, LI (RWL/Load)	1.46	
Population Capable	Male = 95 % Capable Female = 49 % Capable	

Table 31 Shear Operator 3D Static Strength Prediction Program

3D Static Strength Prediction Program
(University of Michigan, 1997)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Plate Shop	Shear Operator
Work Elements: **Manual Placement of Angle Iron Rake Frame Components**		**Disc Compression (lb) @ L5/S1** **(Note: NIOSH Recommended Compression Limit (RCL) is 770 lb)**	
Shear press operator picks up material from the back of the shear, approximate weight 20 pounds (frame#97800)		553 pounds	
Shear press operator lifts plate out of bin at side of shear, approximate weight 20 pounds (frame #99690)		628 pounds	

Table 32. Shear Operator PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date	**Facility**	**Area/Shop**	**Task**
11/9/99	Jeffboat	Plate Shop	Shear Operator

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions.
2) Answer questions, score potential body regions for injury risk.

Musculoskeletal Risk Factor Questions	**Body Regions**				
	Neck, Shoulder, Upper Back	**Elbows, Forearm, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	N	N	N	N	N
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step, etc.			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			Y	Y	Y
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 32. Shear Operator PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work with forearm and hand performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		N			
d) switches or keyboards?		N			

Table 32. Shear Operator PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearm, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**13**	**3**	**2**	**2**	**10**
PERCENTAGE	**50.0**	**27.3**	**25.0**	**25.0**	**47.6**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores.					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	Y				
21:Can the work have unusual or expected situations?	Y				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	**4**				
PERCENTAGE	**40.0**				